



October 26, 1999

Supersedes April 27, 1999

Matls. I.M. 309

METHOD OF TEST
STANDARD PROCTOR MOISTURE DENSITY RELATIONSHIP OF SOILS
FIELD PROCEDURE FOR LABORATORY TEST METHOD 103

NOTE: Charts and graphs will be converted to their metric equivalents for the next I.M. revision.

SCOPE

This test is used to determine the relation between the moisture content and density of soils or base materials compacted according to a modification of standard procedure, AASHTO T-99-81, Method C.

PROCEDURE

A. Apparatus

1. Cylindrical brass mold 101.6 mm (4 in.) in diameter and 116.43 mm (4.584 in.) high having a capacity of 0.00094 cubic meter (1/30 cubic foot), with base plate and collar. A counterbalance equal to the mass (weight) of the mold is useful.
2. Scale, capable of weighing at least 5000 grams and sensitive to 0.5 grams
3. Compaction device, consisting of an arrangement of a 2.495 kg (5.5 pound) hammer inside a cage of 4 metal rods, with the capacity of delivering a 300 mm (12 in.) fall of the hammer to each of three layers of soil. The device shall be bolted to a concrete pedestal of at least 90.72 kg (200 lbs.) mass (weight), or secured to a base giving an equivalent rigidity.
4. A rigid steel straight edge, 225 mm (9 in.) long, with one beveled cutting edge
5. Drying equipment, preferably an oven capable of maintaining a temperature of $110^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ($230^{\circ}\text{F} \pm 9^{\circ}\text{F}$), or a gas hot plate.
6. Mixing equipment. A stainless steel mixing (dish) pan, long handled spoon, rubber or rawhide mallet, putty knife, graduate, and tared weighing scoop
7. Sample extruder, lever or hydraulic type
8. Tared moisture pans

B. Calibration

1. Check the height of hammer fall periodically. With the base plate in position and the hammer stop in the bottom indent, adjust to distance between the base plate and the bottom of the hammer to 343.7 mm (13.53 in.). The nuts holding the cage to the frame shall be well tightened. The hammer shall fall freely and the cage shall be vertical.
2. Calibrate the volume of the brass mold by water content. This should be done in the Central Laboratory at least once a year. Field checks can be made by measurement with a 0.25 mm (0.01 in.) steel rule and appropriate calculations.

C. Sample Preparation

1. Quarter the field sample to a representative sample of about 5000 grams. Spread out and allow to dry to a moisture content at least 5% below the estimated optimum moisture content.
2. Screen the sample over a 19.0 mm ($\frac{3}{4}$ in.) sieve and replace the aggregate retained with an equal weight of 4.75 mm to 19.0 mm (No. 4 to $\frac{3}{4}$ in.) material taken from the original field sample.

D. Test Procedure

1. Pulverize the prepared sample so that 90% of all material except aggregate will pass the 4.75 mm (No. 4) sieve. Place the sample in the mixing pan and sprinkle water on the sample while stirring. The sample is ready for test when, after thorough mixing, a handful of soil squeezed tightly in the palm will barely hold together when pinched between the fingers.
2. Weigh in a tared scoop, and loosely place in the assembled mold, an amount of the dampened sample that, after compaction, will yield 2.5 mm (0.1 in.) more than α the height of the mold. Place the mold under the hammer with the depression in the bottom of the mold base plate over the projection on the base. Put the hammer stop in the lowest indent, raise the hammer with a pulling, flipping motion, so that it will hit the stop firmly, and then let fall freely with no restraint from the chain. Deliver twenty-five such blows with 1/6 turn of the mold base between each blow. Measure to determine if a slight excess over that needed to fill α of the mold is present. Adjust the mass (weight) of soil taken for the second layer as needed to give the desired height, place in the mold, raise the hammer stop to the second indent and compact the same as with the first layer. Repeat this process for a third layer with the hammer stop placed in the top indent. During this entire operation, do not allow sample to accumulate on the bottom of the hammer or on the cage rods.

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3. Move the mold and contents to a table, remove the collar with a twisting motion and cut off the excess sample in thin layers with the straightedge. If the soil projects more than 9.5 mm ($\frac{3}{8}$ in.) above the mold or if the mold is not completely filled, the compactive effort is incorrect and the compacted specimen must be extruded pulverized and returned to the mixing pan. After remixing, adjust the mass (weight) for each layer as needed and recompact by the same procedure. Replace any small aggregate which are pulled from the surface with finer hand tamped material. Leave in place large, well-embedded aggregate, and finish the top to arrive at a surface that will average level full.
 4. Detach the mold and contained specimen from the base plate and weigh, using the mold counterbalance if needed, and cut a vertical pie-shaped moisture sample from the compacted specimen such that the sample and pan together will have a mass (weight) of approximately 500 grams. Weigh this moisture sample in a tared pan, record the mass (weight) and pan number, and then obtain a dry mass (weight) and a moisture loss from which the percent of moisture can be calculated. Pulverize the remaining portion of the specimen and return to the mixing pan.
 5. Sprinkle the sample with water, not to exceed 2% of the remaining sample mass (weight), while constantly mixing until moisture uniformity is reached. The compaction and moisture determination for this moisture content is the same as for the first. Repeat this procedure of adding water, compacting a specimen and taking a moisture sample while increasing the moisture content until a compacted mass (weight) is reached that is lower than the preceding one. This signifies that the resultant moisture density curve is complete and will be past the peak or optimum.

E. Calculations

$$\% \text{ Moisture} = \frac{(\text{Wet soil + pan}) - (\text{Dry soil + pan})}{(\text{Dry soil + pan}) - (\text{pan})} (100)$$

Example:
$$\% \text{ Moisture} = \frac{500 - 460}{460 - 170} (100) = 13.8\%$$

Compacted Dry Density for kg/m³

$$\frac{\text{Net Wet Mass compacted soil} \times 1.0595}{(\% \text{ Moisture} + 100)} (100)$$

Example:

Compacted Dry Density for kg/m³

$$\frac{(1983)(1.0595)}{(13.8 + 100)}(100) = 1846 \text{ kg/m}^3$$

F. Moisture-Density Relationship

1. Make the preceding calculations for each compacted specimen at each corresponding moisture content.
2. Using these results, plot points with densities [mass per cubic meter (dry weight per cubic foot)] as ordinates (vertical) and percent of moisture as abscissas (horizontal).
3. Use the resulting points to draw a smooth curve. The peak of the curve will give the maximum, or Proctor density and the corresponding optimum moisture content.

G. One-Point Procedure

1. Grade material other than crushed stone, gravel, black soils, or soils containing a considerable amount of aggregate may be tested for maximum density and optimum moisture according to this procedure. Those excluded above shall be run as in "D", "E", and "F" above.
2. Moisten a representative sample of approximately 3000 grams to an estimated moisture content of two to three percentage points below Proctor optimum moisture.
3. Following the procedure outlined in D2 through D4, compact and obtain net wet mass (weight) of a single specimen at the moisture content in G2. Determine the moisture content and wet density [in kilograms per cubic meter (pounds per cubic foot)] for this single compacted specimen.
4. In the family of curves, plot the point of intersection of the above wet mass (weight) and moisture. If the plotted point falls outside the "Range of Confidence," recompact another specimen at an adjusted moisture content that will place the plot within these bounds.
5. Using the number of the nearest curve, obtain the dry Proctor density and optimum moisture values from the attached table.

H. Calculations for One-Point Test

Calculate the moisture content and wet mass (weight) sample per cubic meter (foot) as follows:

$$w = \frac{A - B}{B - C} \times 100 \quad W_2 = W_1 (1.095 \text{ kg/m}^3)$$

Where:

w = Percentage of moisture in the specimen, based on oven dry mass (weight) of soil.

A = Mass (weight) of moisture pan plus wet soil.

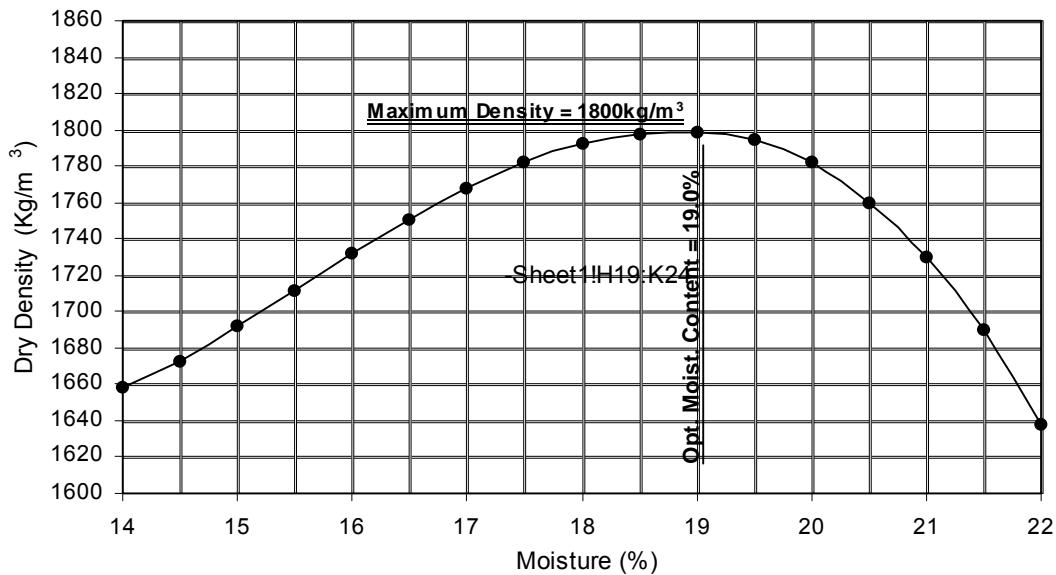
B = Mass (weight) of moisture pan plus dry soil.

C = Mass (weight) of moisture pan.

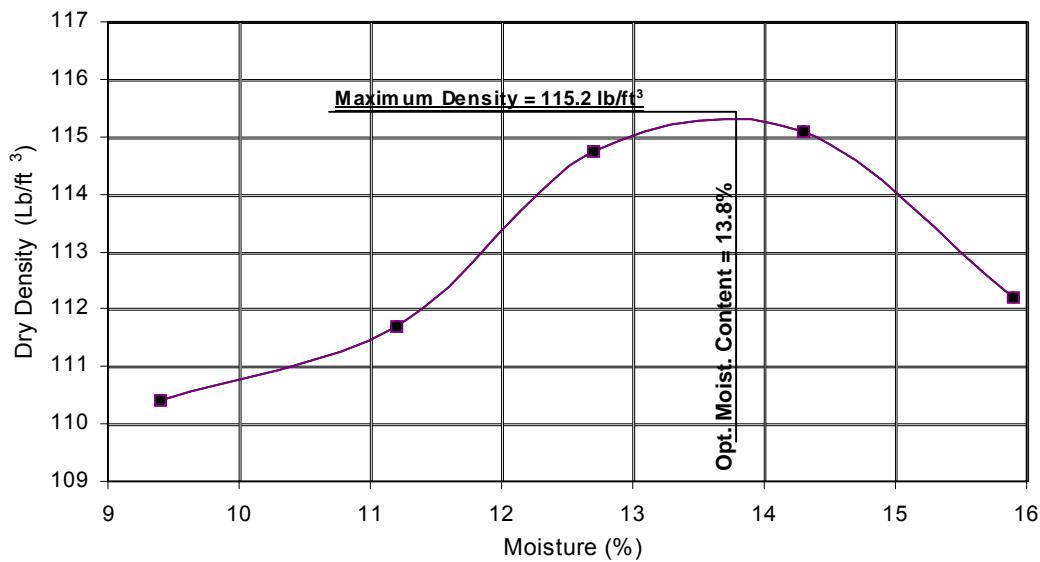
W_1 = Wet mass (weight), in grams, of compacted specimen.

W_2 = Wet mass (weight), in grams per cubic meter (pounds per cubic foot) of compacted specimen.

Multiple Point Proctor Density Curve



Maximum Density Curve



METRIC PROCTOR DENSITY CURVES

<u>Curve No.</u>	<u>Dry Wt.</u>	<u>% Moisture</u>
1	2066	9.8
2	2050	10.1
3	2034	10.4
4	2018	10.7
5	2002	11.0
6	1986	11.2
7	1970	11.5
8	1954	11.7
9	1938	12.0
10	1922	12.3
11	1906	12.6
12	1890	12.9
13	1874	13.2
14	1858	13.6
15	1842	14.1
16	1826	14.5
17	1810	15.0
18	1794	15.5
19	1778	15.9
20	1762	16.3
21	1746	16.7
22	1730	17.1
23	1714	17.5
24	1698	18.0
25	1682	18.5
26	1666	19.0
27	1650	19.6
28	1634	20.2
29	1618	20.7
30	1602	21.2
31	1586	21.7
32	1570	22.2
33	1554	22.7
34	1538	23.2
35	1522	23.7
36	1506	24.3
37	1490	25.0
38	1474	25.6
39	1458	26.2
40	1442	26.9
41	1426	27.5
42	1410	28.1
43	1394	28.7
44	1378	29.4
45	1362	30.0

